A Model of Project Complexity: Distinguishing dimensions of complexity from severity

by:

Dr Kaye Remington, University of Technology Sydney

Dr Roxanne Zolin, Queensland University of Technology

Professor Rodney Turner, Professor of Project Management, Lille School of Management and Kemmy Business School, University of Limerick

Dr Roxanne Zolin
Associate Professor,
School of Management,
Queensland University of Technology
2 George Street,
Brisbane, Queensland, 4001
Australia

Tel: +61 3138 5095
Fax: +61 3138 3138 1313
E-mail: r.zolin@qut.edu.au

Professor J Rodney Turner
Lille School of Management
Avenue Willy Brandt
F59777 Euralille, France

Professor
Centre for Project Management
Kemmy Business School
University of Limerick
Limerick, Ireland

Tel: +33-3-2021 5972
Fax: +33-3-2021 5974
E-mail: rodney.turner@ul.ie

Corresponding Author:

Dr Kaye Remington
1598 Settlers Rd
St Albans, NSW 2775
Australia
Tel: +61 438 682 135
Fax: + 61 245 682 255
E-mail: kaye.remington@uts.edu.au

Research Fellow
University of Technology Sydney
Sydney, Australia

A Model of Project Complexity: Distinguishing dimensions of complexity from severity

Abstract

Key words: Complexity, Project management, Uncertainty, Factors

There is increasing agreement that understanding complexity is important for project management because of difficulties associated with decision-making and goal attainment which appear to stem from complexity. However the current operational definitions of complex projects, based upon size and budget, have been challenged and questions have been raised about how complexity can be measured in a robust manner that takes account of structural, dynamic and interaction elements. Thematic analysis of data from 25 in-depth interviews of project managers involved with complex projects, together with an exploration of the literature reveals a wide range of factors that may contribute to project complexity. We argue that these factors contributing to project complexity may define in terms of *dimensions*, or source characteristics, which are in turn subject to a range of *severity factors*. In addition to investigating definitions and models of complexity from the literature and in the field, this study also explores the problematic issues of 'measuring' or assessing complexity. A research agenda is proposed to further the investigation of phenomena reported in this initial study.

A Model of Project Complexity: Distinguishing dimensions of complexity from severity

Introduction

The development of complexity theory has lead to the observation that organizations, including projects, can be complex (Pundir et al., 2007; Winter et al., 2006; Williams, 1999; Baccarini, 1996) and viewed as complex adaptive systems. Nevertheless current operational definitions of complex projects, based upon size and budget have been challenged (Whitty and Maylor, 2007; Shenhar & Dvir, 2007), who raise research questions about how complexity can be measured in a robust manner, that takes account of structural, dynamic and interaction elements. On the other hand, there is increasing agreement that understanding complexity is important for project management because of the difficulties associated with decision-making and goal attainment that appear to be related to complexity.

There are many definitions of complexity. In this research we define a complex project as one that demonstrates a number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project. These characteristics include high levels of interconnectedness, non-linearity, adaptiveness and emergence. However, our own research and an exploration of the literature reveal a wide range of factors that may contribute to project complexity. We argue that these factors contributing to project complexity may be defined in terms of *dimensions*, or source characteristics, which are in turn subject to a range of *severity factors*. Project complexity models tend to focus either on *severity factors*, factors that exacerbate the complexity, or *dimensions*, factors that characterise the nature of the complexity or a mixture of the two.

In addition to investigating definitions and models of complexity, as they apply to projects, this study also explores the possibility of 'measuring' or assessing complexity. Twenty-five interviews with selected project managers, from one industry, were conducted

and thematically analysed. The interviewees were chosen because they were responsible for projects that had been described by key stakeholders as complex. A research agenda is proposed to further the investigation of phenomena reported in this initial study.

Our long term goal is to develop a way of 'measuring' complexity in projects, or at least to develop ways of exposing its nature and existence to key stakeholders, so that appropriate management decisions can be taken. Given that attempting to measure such an elusive phenomenon as complexity is problematic, we also discuss some epistemological concerns.

Complexity in the literature

Complexity as a field of scientific enquiry

Complexity in the scientific realm is often associated with the degree to which an entity maintains a thermodynamic disequilibrium with its environment. On this basis all living systems, including human social systems, may be described as complex. However there are many definitions of complexity. Several definitions postulate that complexity expresses a condition of numerous elements in a system and numerous forms of relationships amongst the elements (Girmscheid & Brockman, 2008; Moldoveanu, 2004; Williams, 2002; Simon, 1962). At the same time, there is a cognitive aspect. How simple or complex a structure is "depends critically on how we describe it" (Simon, 1962, 481). What is complex and what is simple is relative and changes with time and perspective.

Complexity in the organization science literature

Some models from the general management literature, such as those by Stacey (1996), Kahane (2004) and Snowdon & Boone (2007) focus how complexity, particularly messy or ill-structured problems, might influence leadership style and decision-making in

periods of organizational or social change. Luhmann's (1995) main concern, on the other hand, is on the sociology of communication and how communicative filters determine how the world is recognised. He develops a comprehensive, universal theory with flexible networks of interrelated concepts that can be used to describe the most diverse social phenomena.

Complexity from a systems perspective

Definitions are often tied to the concept of a 'system' – a set of parts or elements in which relationships within the system are differentiated from relationships with other elements outside the relational regime. Approaches, which embody concepts of systems, multiple elements, multiple relational regimes, and state spaces, imply that complexity arises from the number of distinguishable relational regimes (and their associated state spaces) in a defined system. Weaver (1948), for example, has posited that the complexity of a particular system is to do with the degree of difficulty in predicting the properties of the system if the properties of the system's parts are given As Simon (1962) has argued, complex systems are made up of large numbers of multiple-interacting components in which it is difficult to or understand the behaviour of the individual components or predict the overall behaviour of the system, based on knowledge of the starting conditions . System complexity has also been defined "objectively", by Moldoveanu (2004), as structural intricacy which takes into account the number of parts and the interconnectedness, while allowing the system to be classified as simple, complicated, complex or chaotic.

Complexity associated with projects

The goal-seeking focus of the project management discipline has produced a number of approaches which attempt to address project complexity. Qualitative differences in projects have been recognised for some time. Early methods include Turner and Cochrane's (1993) 'Goals and Methods Matrix', and the Declerck & Eymery (1976) method for analysing ill-structured projects.

Most authors have tended to focus on *uncertainty*, (De Meyer et al., 2002; Williams, 2005); *difficulty*, to do with technical or management challenges (Turner and Cochrane, 1993) or organisational complicacy (Laufer, et al. 1996; Baccarini, 1996; Williams, 2002). Others have used *systems theory* to help understand how these aspects affect the project as a system (Baccarini, 1996; Williams, 2002; Remington & Pollack, 2007). Payne (1995) takes a perspective which combines difficulty and systems thinking, associating complexity with the multiple interfaces between individual projects, the organization and the parties concerned. Laufer, et al. (1996) explore the evolution of management styles associated with simple and complex projects. Taikonda & Rosenthal (2000) and Pundar et al., (2007), relate technological novelty to technological maturity of the organization, immaturity leading to task uncertainty.

Fitting into the broad category of *uncertainty*, De Meyer et al. (2002) associate categories of uncertainty with variations, foreseen uncertainty, unforeseen uncertainty and chaos. Williams (2005) defines two types additional types of uncertainty: aleotoric, uncertainty relating to the reliability of calculations, which can be alleviated by contingency planning and epistemic uncertainty, stemming from lack of knowledge and leading to project complexity.

How complexity contributes to complexity in projects.

Whilst disagreement exists about the relevance of complexity as a concept to project management (see for example, Frame, 2002; Stephen and Maylor, 2009; Whitty & Maylor, 2008), articles associated with complexity, chaos and uncertainty are steadily increasing in the PM research literature (Clift & Vandenbosch, 1999; Austin et al, 2002; Jafari, 2003; Ivory & Alderman, 2005; Hass, 2007; Geraldi, & Adlbrecht, 2007; Vidal & Marle, 2008; Thomas & Mengel, 2008). However clear or agreed distinctions between what differentiates complicated or difficult projects from those projects that might be considered to be complex have yet to be agreed.

Girmscheid & Brockman (2008), maintaining a structurally-based approach, argue that any difference between a complicated project and a complex project has to do with the number of elements (complicated) as opposed to the relationships between the elements (complex). Also the association of linearity with complicated projects and non-linearity with complex projects implies, that non-linearity makes the relationship between inputs and outputs unpredictable (Richardson, 2008).

Some authors (Baccarini, 1996; Williams, 1999; Remington and Pollack, 2007) have attempted to arrive at a more precise definition of the word 'complex', as it pertains to projects, by appropriating concepts from complexity theory to describe what might happen in these projects which are more than just difficult. For these authors, a complex project can be described as one which consists of many varied interrelated parts and which can be operationalized in terms of *differentiation* and *interdependency*. In terms of organizational complexity, differentiation would mean the number of hierarchical levels (vertically and horizontally defined), number of units, division of tasks, etc. 'Interdependency' would be the degree of operational interdependencies between organizational elements. Technology can be divided into three areas: operations, characteristics of materials, and characteristics of knowledge (Baccarini, 1996). Jones and Deckro (1993) add another aspect to technical complexity; that of instability of the assumptions upon which the tasks are based.

Dimensions and severity factors.

Our research into project complexity suggests that not all projects are complex in the same way. Therefore there is, potentially, more than one source of complexity in a project, such as level of interconnectedness, lack of clarity of goals, means to achieve goals (i.e. technology). Understanding the source of the complexity and to what degree the resultant difficulties will be played out might help us to determine the skills and capabilities needed to deal with the problem. Hence, we propose an operational distinction between the terms d*imension* of complexity, which tells us where the complexity comes from and the *severity*,

which tells us to what extent it will be a problem. A *severity factor* can affect any dimension of complexity and for each dimension of complexity the *severity* of the complexity is likely to differ. An example of a severity factor is lack of trust. A lack of trust between key players could affect all aspects of the project causing uncertainty. With this understanding we turn to the literature and summarize our findings in Tables 1 and 2 at the end of the document. Table 1 indicates *severity factors* identified by article. Nine severity factors were identified in the literature. Table 2 indicates *dimensions* identified by article from the literature. Five dimensions were identified.

Danilovic & Browning (2007); Alderman and Ivory (2007); Cooke-Davies et al., (2007); Aritua et al. (2008) have all highlighted similar attributes namely inter-relationships, self-organisation, emergence, feedback and non-linearity and have discussed these effects in multi-project situations. Although complexity is still being used as an umbrella term associated with difficulty and interconnectedness (Geraldi, 2008), typically, the characteristics of a complex project would include both difficulty and uncertainty.

Uniqueness, indirect communication among elements (Luhmann & Boje, 2001; Kumar, et al., 2005), dynamism (Kallinikos, 1998) and lack of clarity on the goals of the project (Turner & Cochrane, 1993) are also cited. Vidal & Marle (2008) argue that project complexity can be characterized into four families. All are necessary but non-sufficient conditions for project complexity. They are project size, project variety, interdependencies and interrelations and context-dependence.

Geraldi (2008) takes a slightly different approach when she talks about complexity of faith, complexity of fact and complexity of interaction. Geraldi & Adlbrecht (2007) have concluded that these factors vary over the life cycle of a project. Trust, as an organizational capability, is also suggested as a significant issue for complexity in IT related projects (Müller & Geraldi, 2007). D'Herbemont and César (1998), develop a matrix model for classifying projects comprising two categories, technical and human. Their technical category appears to be a *dimension*, while their human category could apply to any dimension of project

complexity and therefore might be considered to be a *severity* factor.

Amongst the latest contributors are Remington and Pollack (2007) who provide a starting point for categorizing complex projects into four types or *dimensions*, based on the source of complexity: Structural, Technical, Directional and Temporal. They emphasize that a clear understanding of the source of complexity helps in selecting appropriate tools and approaches to manage the project. Structural complexity stems from potential non-linear, emergent behaviour which can occur from interactions between many interconnected tasks. Technical complexity is found in projects which have design characteristics or technical aspects that are unknown or untried. Directional complexity is found in projects where the goals or goal-paths for the project are not understood or agreed upon at all levels of the project hierarchy. Temporal complexity refers to volatility over the duration of the project, where project durations are extended and where the environment (market, technical political or regulatory) is in a state of flux and can affect the project direction. These can be seen as dimensions of complexity

Because a project, or any part of a project, is dynamically poised along a continuum from order to chaos, at any moment in time any of these types of complexity, each based on its source, may be found in any combination and at varying levels of *severity*. The level of *severity* perceived, in relation to each of the four types or dimensions of complexity in Remington & Pollack's (2007) model, depends upon the following factors: the breadth and depth of experience and capability of key personnel in relation to the type and degree of complexity; the project organisational structure, and its interfaces with key participating organisations, with respect to communication and governance; existing cultural norms and work practices within and between participating organisations, including project culture; appropriateness of organisational processes, such as procurement practices, to the type(s) of complexity experienced.

Their argument goes some way towards clarifying the wide-spread use of the term 'uncertainty'. Uncertainty is caused by the *dimensions* and possibly exacerbated by other

factors once it is present. If there is structural complexity - the non-linear behaviour, particularly the separation of cause and effect in time and space causes uncertainty. People can't predict anything any more. Technical complexity means that people are uncertain about whether or how they are going to solve the problem and achieve their goals. If there is directional complexity - the confusion causes uncertainty. If there is temporal complexity the uncertainty comes from not knowing what is going to hit the project next. Uncertainty then is likely to become a 'state of mind' which affects the way the project team and stakeholders (including clients, customers and suppliers) operate from then on (Remington & Pollack, 2007). Uncertainty is a state of mind which derives from 'objective' causes and then comes back to bite the project. At this point uncertainty becomes a *severity* factor.

Measuring complexity

Complexity as it applies to organization theory has been construed as an "objective characteristic of either the structure or behaviour of an organization" (Fioretti & Visser, 2004, 11). However Moldoveanu (2004) exposes an epistemological problem connected to the problem of defining and defending a complexity measure for organizational, and in this case, project phenomena. In particular Moldoveanu (2004:1) questions the possibility of obtaining intersubjective validity in any 'measurement' of complexity, as "how would we know a complex phenomenon if we saw it… or how can complexity of different phenomena be compared?" Computational methods of modelling complexity abound but they are unlikely to be practical. Reliance on computational methods may actually avoid the problem of measuring complexity since the aspects of complexity that are ambiguous, not understood or not known, cannot be modelled, regardless of efficacy of the model. The process of measurement is also complicated because the ability to define or measure organizational complexity is itself defined by the model chosen, the ability of the assessor to apply the model, the presence of the assessor, him or herself, and the information known or not known or indeed unknowable about the system. In reality we are not going to be able to fully define or measure complexity because we are dealing with the unknown.

Nevertheless there is wide agreement that complexity is important because it causes problems, and indeed, "it could be argued that complexity matters only because of the cognitive problems it gives rise to" (Fioretti & Visser, 2004, 12); that is how it is understood by the people who are affected. Therefore, in parallel with other authors (Fioretti & Visser, 2004; Rescher, 1998; Simon, 1962) we argue that complexity is most usefully conceptualised in cognitive terms. In relation to everyday practice, perception, and possibly also 'measurement', of both the dimensions and the severity of project complexity is dependent upon how the people involved construe the structure and behaviour of the system. In addition, our research to date supports the observation that, at any point in time, even if one person were able to recognize complexity in a system, other players might have a very different understanding of what that complexity looks like, or might not perceive that complexity is present at all. Perceptions of both the dimensions of complexity and its severity vary between individual observers and over time.

A cognitive approach to assessing complexity takes into account the fact that different people associated with the project will have different perspectives. Differing perspectives may be based on their places within the structure or backgrounds and experience; for instance, the novice does not necessarily see aspects of complexity that the experienced person sees and the novice might perceive something to be complex that an experienced person might see as simply challenging. Finally individual personality characteristics are also likely to influence how the complexity is perceived – exemplified by differences in world view between a specialist and a generalist.

Summary of the literature

Complex organizational phenomena are being explored from a number of theoretical positions. Models of project complexity tend to focus on uncertainty and/or difficulty, many from a systems perspective. Some models confuse dimensions, or characteristics of complexity, with severity factors, those factors which increase or decrease the experience of

the complexity. Although complexity is being modelled by a number of researchers, ontological and epistemological issues associated with measuring complexity have been raised, particularly when measurement implies prediction. Attempts have been made to measure the 'objective' status of a complex system using computational approaches however there are restrictions associated with the strength of the model chosen and there are also questions about the practicality of computational methods. A cognitive approach takes into account the perceptions of key players, who are themselves, dynamic entities in the system, in the understanding that those perceptions will vary from person to person and from time to time.

Research method

Research site

Within Australian Defence, defence acquisition projects are rated for complexity using the Acquisition Categorisation (ACAT) framework. ACAT I and II projects are major projects with multi-million and billion dollar budgets, high uncertainty and risk, emergent technology, multiple contractors, and often geographically dispersed teams. ACAT III minor projects tend to have smaller budgets and only moderate levels of uncertainty, risk and emergent technology. Managers from Defense Materiel Organisation (DMO) and external stakeholders (e.g., clients, defence contractors) of projects rated ACAT 1 through 3 form the sampling frame for this study. These senior-ranked people were targeted because they have unique knowledge about the management of projects that are generally considered to be moderate to complex.

The participants were recruited from the Commonwealth Department of Defence (including the DMO), the College of Complex Project Managers (CCPM); now referred to as the International Centre for Complex Project Managers) and Defence Contractors such as Lockheed-Martin, Boeing, Raytheon and BAE Systems. All 'preferred' interviewees agreed to participate in the study. In addition to ACAT experience, purposive sampling was also used to ensure that participants, as a whole, represented the views of both male and female project

managers, both civilian and military perspectives, and experience with a wide range of defence acquisition projects. Forty project managers of were initially sourced, but data saturation was reached after interviewing 23 participants. Thus, 23 leaders who had project management experience in projects rated ACAT I, II and/or III participated in in-depth semi-structured interviews of approximately one hour.

Interview Process and Analysis

At least two researchers sat in on each interview: one principally acted as the interviewer, the other collected field notes. Strict research ethics and security guidelines explained and followed. Data collection and analysis occurred concurrently as suggested by Carpenter (1995). Initially, the taped interviews were compared with previously taped interviews to determine emerging themes. This preliminary analysis guided subsequent interviews. As themes emerged, the process of interviews was accelerated. In-depth analysis was conducted once all the interviews were completed.

Participants were asked to respond to the question: “What makes a project complex, in your opinion?”Once interviews were transcribed and de-identified, the data were examined sentence-by-sentence and analysed for meaning, for points or issues of interest with the research questions in mind. Coding categories were assigned to segments of text according to the meaning ascribed to that section. Categories were clustered into higher order categories, according to emerging meaning. A constant comparative method was used to analyse data within and between these categories.

The process of coding and analysing enabled the researchers to become intimately familiar with, or immersed in, the data, and to be able to see the data from different angles, thus enabling development of constructs that explain the data (Janesick, 1994). Comparison of each piece of data with other data enabled emerging themes to be tested by comparing for similarities and differences. The developing constructs could be constantly compared with new data for consistencies and inconsistencies. Strauss and Corbin (1990) describe this

method of analysis as interpretive, in that the actions and experiences of the people studied have been interpreted rather than described.

Results

Key themes

In this section we report key themes by condition, with the descriptive and inferential statistics. Exemplar quotes are presented in Table 3. We noticed that the majority of interviews identified the source of complexity, whereas others referred to the severity of complexity. **Uncertainty** was an overarching theme that seemed to define complexity for those who mentioned it: "I think ambiguity and uncertainty are part of what makes something complex." "The huge amount of uncertainty, change, and a change management process which just appears out of the ether and catches you off guard, so you have to understand the environment in which you are operating." However because it was an overarching theme, and because its meaning is potentially contentious it was treated separately from the other categories.

The interviews revealed a number of specific topics which seemed to contribute both to the perception of complexity. They have been broadly grouped under the following thematic headings: ***Goals, stakeholders, interfaces and dependencies, technology, management processes, work practices and time***. Table 4 provides a breakdown of key topics and instances reported.

Goals

Under the general theme ***goals,*** the instances reported included goals expressed at a high level but which proved to be ill-determined at a practice-level, customers being unclear about goals and objectives, incomplete or inadequate requirements definition, and earlier decisions which were no longer applicable. *"…and the requirements weren't sorted out, as is common with major projects, well enough or early enough…"*

Stakeholders

Many instances reported which were grouped under the theme ***stakeholders***. They include multiple senior stakeholders, changing senior stakeholders, clients with unrealistic goals, multiple suppliers, high visibility and politically sensitive, lack of control due to multiple project owners or customers, varying stakeholder engagement, changing requirements and ambiguity or incomplete information. *"A lot of people have interest in it, including at government level.'*

Interfaces and interdependencies

The thematic group ***interfaces and interdependencies*** included reported lack of control due to multiple platforms and systems integration issues, lack of control due to multiple owners, different design philosophies across platforms, interdependencies on other projects, integration problems associated with upgrading or retrofitting, cross-organisational interdependencies, schedule interdependencies and quality integration issues.*"…so many interfaces and interactions and systems that have to come together…."*

Technology

Only three major groups of instances were mentioned under the thematic group ***technology***, but they were mentioned frequently. The three instances were, innovation, or cutting-edge technology, technological difficulties generally and changing technology. *"…stepping into the unknown from a technology point of view."*

Management processes

The general theme ***management processes*** was derived from a number of different instances, which varied from contractor relationships and procurement choices, to contractor ethics, supplier monopolies and overlapping of processes due to concurrent engineering.*"…often the contract doesn't support us working like that … it is an old contract which doesn't help." "… once we start to introduce these capabilities we start work on development of the next phase*

... You're constantly juggling …."

Work practices

Work practices as a broad theme covers several recurring instances associated with cultural differences between participating departments and organisations as well as different participating nations, time differences associated with international projects, appropriateness of project personnel selection, language differences, both between participating organisations and between nations, inappropriate project methodology and micro-reporting. *"I think dealing with different countries even though we all spoke English. The US refers to things differently; the UK refers to things differently; and so do we, and also the remoteness."*

Work *practices* was coded when respondents mentioned the project cost or budget consciousness or the respondent said, for example, *"…cost leads to a level of nervousness and stress which can lead to complexity."* It is important to mention that while some viewed budget pressure as increasing complexity others viewed budget as nothing more than an expected constraint rather than something which would lead to complexity.

Time

On the other hand ***Time*** was frequently mentioned as having differing effects on the perception of complexity for the participants and therefore was treated as a separate theme. Under the general theme of *time* were instances which included change of decision makers over time, extended project history and pre-history that influenced subsequent decisions, instability of requirements definition over time, key relationships changing over time and project plans frequently being re-shaped. *"…because when it was signed many years ago, it didn't understand the sorts of complexity that we're coming up against now."*

Discussion

We found that respondents discussed complexity both in terms of dimensions, or sources of complexity, and in terms of severity factors, which exacerbate the complexity as

experienced and may affect any or all of the dimensions of complexity. For example, structural intricacy and technical challenges might be considered to be dimensions or sources of complexity which can be affected by lack of trust between key players, which is a severity factor.

Comparison of the data and the literature

We compared the results from project managers, who had managed what are perceived in that industry to be complex projects, with our analysis of the literature, which was not in itself exhaustive. To do this we sorted the themes mentioned by the project managers into the severity factors and dimensions found in the literature. Table 5 compares the instances of severity factors found in the literature with (Table 1) with themes from the data that also indicate severity.

Difficulty was identified as a severity factor from the literature but difficulty was not manifested as a theme once the analysis was conducted, suggesting that it is not a legitimate category but one that is implied in other themes cited. A severity factor that featured prominently in the literature that was not reported by the respondents was *non-linearity*. However this might be explained on the basis that non-linearity is a theoretical construct used by complexity theorists to describe behaviour in which the cause and effect are unrelated in time and space. The fact that respondents did not mention non-linearity is therefore entirely reasonable. It simply exemplifies a disconnection between theoretical and practice-based terminology and understanding.

The most frequently reported severity factors corresponded with the general heading of contextual factors from the literature. Although this had been recognised as a heading by a number of authors it is a category that might need further investigation as it seems to be affecting severity from a number of angles; including issues such as prior decisions difficult to accommodate; multiple and changing senior stakeholders; multiple customers and suppliers; high political sensitivity and visibility; geographic distances and different time

zones; cultural differences, internal, inter-departmental and international; extant administrative processes, including micro-reporting and the adequacy of project methodologies and budgetary pressures. All of these are context specific variables. Clarity was another severity factor that was identified in the literature and played out in terms of; lack of clarity about goals on the part of customers and team; inadequate requirements definition; changing stakeholder requirements; lack of control due to multiple interfaces and owners; split accountabilities and subsequent unclear authority

Other severity factors found in the literature (communication, trust and capability) were less heavily represented in the data.

Table 6 compares the instances of complexity dimensions found in the literature with (Table 2) with themes from the data that also indicate sources of complexity. The complexity dimensions cited appeared to support those reported in the literature in relation to the categories discussed earlier; goals (High level goals/ ill-determined), means of achieving goals (Different design philosophies across platforms), number of interdependent elements (Systems integration / multiple platforms), timescale (Change of decision makers over time) and environment (Changing technological environment).

In conclusion for this sample of respondents the majority of dimensions of complexity related to means to achieve goals, number of interdependent elements and timescale of project.

Implications

The theoretical implications of these findings are that there needs to be clearer distinction between of the dimensions of complexity and the severity of each dimension. Identification of the potential sources of complexity could also benefit the dialogue between project managers and stakeholders in their discussions of project complexity.

Limitations and future research

The interviews were necessarily limited to a selected sample of project managers from one single industry. An analysis of frequency of responses in any particular category was inappropriate due both to the size of the sample and the selection process. The seven themes, or groupings which emerged from secondary coding of reported instances, are neither mutually exclusive nor definitive. Some statements had implications which extended over more than one thematic grouping. Also, except where reported in a general sense, an analysis of frequency was not made. The high frequency of reporting associated with technological complexity due to development of leading-edge technology is expected due to the nature of the sample. Equally, frequent reporting of complexity associated with culture and language differences reflect the inter-agency and international interfaces that were associated with the projects concerned.

This initial study will inform the design of a large scale research project within to determine the key severity factors affecting project complexity.

Conclusion

The research literature testifies that increasing understanding of complexity is important for project management. The current operational definitions of complex projects, based upon size and budget have been challenged and research questions raised about how complexity can be measured in a robust manner, that takes account of structural, dynamic and interaction elements.

There are many definitions of complexity. In this research we have defined a complex project as one that demonstrates a number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project. However, our research data together with an exploration of the literature reveals a wide range

of factors that may contribute to project complexity. We argue that these factors contributing to project complexity may be defined in terms of *dimensions*, or characteristics or sources of complexity, which are in turn subject to a range of *severity factors*.

In addition to investigating definitions and models of complexity, as they apply to projects, this study also explores the possibility of 'measuring' or assessing complexity. Twenty-five interviews with selected project managers, from one industry, were conducted and thematically analysed as a part of a pilot study to explore the efficacy of the literature in relation to actual experience of complexity in practice. Based on a qualitative thematic analysis correlations between lived experience and the research data appear to be high with a stronger emphasis on context and clarity, which appear to be key severity factors for the industry under study.

In full recognition that attempting to 'measure' such an elusive phenomenon as complexity is problematic, we have opted for a cognitive approach to measurement which takes into account the perceptions of those experiencing the complexity. Using this pilot study as a first step, our long term research agenda is to develop a way of 'measuring' complexity in projects so that complexity can addressed in practice more effectively.

References

Alderman, N. and Ivory, C. 2007. Partnering in major contracts: Paradox and metaphor. *International Journal of Project Management*. 25(4):386-393.

Austin, S., Newton, A., Steele, J. and Waskett, P. 2002. Modelling and managing project complexity, *International Journal of Project Management* 20(3), 191-198.

Baccarini, D. 1996. The concept of Project complexity - a review. *International Journal of Project Management , 14* (4), 201-204.

Chaitin, G. 1974. Information-theoretic computational complexity, IEEE Transactions on Information Theory, 20, 10-30.

Clift, T.B. & Vandenbosch, M.B. 1999. Project Complexity and Efforts to Reduce Product Development Cycle Time, *Journal of Business Research* 45(2), 187-198.

Cooke-Davies, T., Cicmil, S., Crawford, L., and Richardson, K. 2007. We're not In Kansas Anymore, Toto: Mapping the Strange Landscape of Complexity Theory, and its Relationship to Project Management. *Project Management Journal.* 2007 Jun; 38(2):50-61.

Danilovic, M., & Browning, T. 2007. Managing complex product development projects with design structure matrices and domain mapping matrices. *International Journal of Project Management , 25,* 300-314.

Davidson, F. J. (2002). *The New Project management.* Wiley & Sons.

Declerck, R. P. et Eymery, P. 1976. Le management et l'analyse des projets. Description de la méthode M.A.P et cas d'application. Suresnes, France: Editions Hommes et Techniques.

D' Herbemont, O. and César, B. [Curtin, T. and Etcheber, P. (Eds)] 1998. *Managing Sensitive Projects: A Lateral Approach*. New York: Routledge.

De Meyer, A., Loch, C.H. and Pich, M.T., 2002, Managing project uncertainty: From variation to chaos. *MIT Sloan Management Review*. **43**(2) 60-67.

Dombkins, D. 2008. The integration of project management and systems thinking. Project Perspectives 2008, Annual Publication of International Project Management Association , 16-21.

Fioretti, G. & Visser, B. 2004. A cognitive interpretation of organizational complexity. *E:CO Special Double Issue.* **6**(1-2) , 11-23.

Geraldi, J. 2008. Patterns of complexity: The thermometer of complexity. *Project Perspectives 2008, The Annual Publication of International Project Management Association* , 4-9.

Geraldi, J., & Adlbrecht, G. 2007. On faith, fact and interaction in projects. *Project Management Journal , 38* (1), 32-43.

Girmscheid, G., & Brockman, C. 2008. The inherent complexity of large scale engineering projects. *Project Perspectives, annual publication of International Project Management Association* , 22-26.

Hass, K. 2007. *Managing Complex Projects. A New Model.* Management Concepts

Jansick, V.J. 1994. The dance of qualitative research design. In Norman K. Denzin and Yvonna S. Lincoln. (Eds.) Handbook of qualitative research, 209-219, London: Sage.

Jones, R., & Deckro, R. 1993. The social psychology of project management conflict. *European Journal of Operational Research , 64,* 216-228.

Ivory, C. and Alderman, N. 2005, 'Can Project Management Learn Anything from Studies of Failure in Complex Systems?' *Project Management Journal* 36:3, 5-16.

Jaafari, A., 2003. *Project Management in the Age of Complexity and Change.* Project Management Journal,. **34**(4): p. 47-57.

Kahane, A. 2004. *Solving Tough Problems: An Open Way of Talking, Listening, and Creating New Realities.* Berrett-Koehler Publishers.

Kallinikos, J. 1998. Organized Complexity: Posthumanist Remarks on the Technologizing of Intelligence. *Organization , 5*, 371-296.

Kumar, R., Rangan, U., & Rufin, C. 2005. Negotiating complexity and legitimacy in independent power project development. *Journal of World Business* , **40**, 302-320.

Laufer, A., Gordon, R. D., & Shenhar, A. J. 1996. Simultaneous management: The key to excellence in capital projects. *International Journal of Project Management* , **14** (4), 189-199.

Luhmann, N. 1995. *Social systems.* Stanford, CA: Stanford University Press.

Luhman, J., & Boje, D. 2001. What Is Complexity Science? A Possible Answer from Narrative Research. *Emergence: Complexity and Organization* , **3** (1), 158–168.

Moldoveanu, M., 2004. An intersubjective measure of organisational complexity: A new approach to the study of complexity in organizations. *Emergence:*

Complexity and Organization, **6**(3), 9-16.

Muller, R., & Geraldi, J. G. 2007. Linking complexity and leadership competences of Project Managers. *IRNOP VIII Conference (International Research Network for Organizing by Projects).* Brighton.

Muller, R. and Turner, J. R. 2007. Matching the project manager's leadership style to project type. *International Journal of Project Management.* **25**(1):21-32.

Payne, J. 1995. Management of multiple simultaneous projects: a state-of-the-art review. *International Journal of Project Management* , **13** (3), 163-168.

Payne, J.H. and Turner, J.R. 1999, 'Company-wide Project Management: The Planning and Control of Programmes of Projects of Different Type', *International Journal of Project Management*, **17**(1), 55-9.

Pundir, A.K., Ganapathy, L., and Sambandam, N., 2007, Towards a complexity framework for managing projects. *E:CO*. **9**(4) 17-25.

Rescher, R. 1998. *Complexity: A philosophical overview*, New Brunswick, NJ: Freeman & Co.

Remington, K., & Pollack, J. 2007. *Tools for Complex Projects.* Aldershott, UK: Gower Publishing company.

Richardson, K. 2008. Managing complex organizations: Complexity thinking and the science and art of Management. *Emergence: Complexity and Organization* , **10** (2), 13-26.

Santana, G. 1990. Classification of Construction projects by scales of complexity. *International Journal of Project Management* , **8** (2), 102-104.

Shenhar, A.J. 2001, One Size Does Not Fit All Projects: Exploring Classical Contingency Domains', *Management Studies* **47** (3), 394–414.

Shenhar, A. and Dvir, D. 2007. *Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation*, Boston: Harvard Business School Press

Simon, H.A., 1962. The architecture of complexity. Reprinted in H. Simon, 1982. *The sciences of the artificial*, Cambridge, MA: MIT Press.

Simon, H. A., 1973. The Structure of Ill-Structured Problems, *Artificial Intelligence*, **4**, 181-201.

Snowden, D. F., & Boone, M. E. 2007. A Leader's Framework for Decision making. *Harvard Business Review* , 69-76.

Stacey, R. D. 1996. *Complexity and Creativity in Organizations.* Berrett-Koehler Publishers.

Stephen, W. J., & Maylor, H. 2009. And then came Complex Project Management. *International Journal of Project Management* , **27**(3), 304-310.

Strauss, A., Corbin, J. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, 1st Ed., London, UK: SAGE Publications.

Taikonda, M.V, and Rosenthal, S.R., 2000. Technology, novelty, project complexity and product development project execution success: A deeper look at task uncertainty in product innovation. *IEEE Transactions on Engineering Management*, 47(1), 74-87.

Thomas, J. & Mengel, T. 2008. Preparing project managers to deal with complexity - Advanced Project Management education. *International Journal of Project Management , 26* (3), 304-315.

Turner, J. R., & Cochrane, R. A. 1993. Goals-and-methods matrix: coping with projects with ill defined goals and/or methods of achieving them. *International Journal of Project Management , 11* (2), 93-102.

Vidal, L-A. and Marle, F. 2008. Understanding project complexity: implications on project management, *Kybernetes,* 37(8), 1094-2001.

Weaver, W. 1948. Science and Complexity, *American Scientist* **36**: 536 (Accessed on 2007–11–21.)

Whitty, S.J., and Maylor, H., 2007. And then came complex project management. 21st IPMA World Congress on Project Management.

Winter, M. Smith, C., Morris P., and Cicmil, S., 2006, Directions for future research in project management: The main findings of a UK government-funded research network. *International Journal of Project Management*. **24**, 638-649.

Williams, T. M. 1999. The need for new paradigms for complex projects. *International Journal of Project Management* , **17** (5), 269-273.

Williams, T. 2002. *Modelling Complex Projects.* John Wiley & Sons, Ltd.

Williams, T. 2004. 'Why Monte Carlo Simulations of Project Networks can Mislead', *Project Management Journal*, **25**(3), 53-61.

Williams, T.M., 2005. Assessing and moving on from the dominant project management discourse in the light of project overruns. IEEE Transactions on Engineering Management, **52**(4), 497-508.

Table 1: Complexity severity factors identified by article (severity increases experienced level of complexity).

Citation	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
	Difficulty	Non-linearity	Uncertainty	Uniqueness	Communication	Context dependence	Clarity	Trust	Capability
Turner & Cochrane, 1993							Lack of clarity		
Kallinikos, 1998						Dynamism			
D'Herbemont and César (1998									Human
Luhmann & Boje, 2001				Unique-ness	Indirect comm.-unication				
Williams, 2002	Difficulty	Inter-connected	Un-certainty estimates						
Müller & Geraldi, 2007								Lack of trust	
Remington & Pollack, 2007		Non-linearity	Un-certainty			Org. culture/ work practices/ processes			PM capability/ sponsors support
Müller & Geraldi (2007)								Trust	
Danilovic & Browing (2007)		Inter-relations							
Alderman & Ivory (2007)		Inter-connect-ivity							
Pundir, et al., (2007)						Context and history			
Cooke-Davies et al. (2007)		Inter-connect-ivity							
Geraldi (2008)	Difficulty	Inter-connect-ivity						Trust	
Aritua et al. (2008)		Inter-connec-tivity							
Vidal & Marle (2008)		Inter-dependent				Context dependent			

Table 2: Dimensions of complexity identified by article.

Citation	Dimension 1 Goals	Dimension 2 Means to achieve goals	Dimension 3 Number and interdependency of elements	Dimension 4 Timescale of project	Dimension 5 Environment – market, poltical, regulatory.
D'Herbemont and César (1998)		Technical: Innovation,	Number of people Number of stages	Time-scale of the project	Financial investment Risks in the event of failure
Baccarini (1996), Williams (2002)			Number of elements - Interdependent elements		
Remington & Pollack (2007)	Directional – clarity and agreement on goals and goal-paths	Technical – level of technical innovation	Structural – number and interdependence of elements	Temporal - Duration of project	Temporal - Dynamism of the market, political or regulatory environment
Vidal and Marle (2008)		Variety	Size Interdependent		Context dependence

Table 3: Themes with sample quotations from the research data.

Theme	Sample quotes from the data
1. Goals	▪ *"…a simple one line requirement,"* ▪ *"…and the requirements weren't sorted out, as is common with major projects, well enough or early enough…"* ▪ *"…or the original customer, if he doesn't quite know what he wants, or thinks he knows, but doesn't convey that very well …".*
2. Stakeholders	▪ *"… where you have a huge number of different stakeholders, all with different types of interests, motivations, …. "* ▪ *"A lot of people have interest in it, including at government level.'* ▪ *"I think having a very demanding and knowledgeable client creates a huge amount of issues for the project manager. …. ."*
3. Interfaces and interdependencies	▪ *"The huge, the demanding schedule complexities, …because some schedules are so tight they're impossible …"* ▪ *"All of that cross project, cross organisational complexities, and not just cross project, …."* ▪ *"… because it has so many interfaces and interactions and systems that have to come together , it makes it complex."*
4. Technology	▪ *"… what it is you're trying to do and whether it's been done before or whether it hasn't been done before."* ▪ *"…stepping into the unknown from a technology point of view."* ▪ *"…oh well, there's the next generation of this technology is in the wings, and we'd like to consider that ... led to a redesign on my installation into the ships."*
5. Management processes	▪ *"…often the contract doesn't support us working like that because when it was signed many years ago."* ▪ *"…. You're constantly juggling between making sure these capabilities are introduced into service properly."* ▪ *"but our business processes don't allow for a seamless path in many cases"*
6. Work practices	▪ *"…culture, so if you're working with the Americans, they're very close allies, but in some ways they think differently"* ▪ *"…contractor in Brisbane and we're here in Melbourne, another contractor in Sydney, one in Israel, one in the USA,."* ▪ *"…tyranny of distance ...time differences,…so we have liaison and time difference issues* ▪ *"There are cultural differences, no matter who you deal with, but dealing with a European contractor, … and so it's a bit of learning experience in terms of how to manage all of that relationship in terms of interpretation…"*
7. Time	▪ *"By their nature, complex projects have a quite long duration and during this time there are ...you're living in a very rapidly changing …"* ▪ *"…so many moving parts that you're trying to integrate."*

Table 4: Key themes and instances from the research data.

Theme	Instances reported
Goals	▪ High level goals/ ill-determined ▪ Customer unclear about goals ▪ Inadequate requirements definition ▪ Prior decisions difficult to accommodate
Stakeholders	▪ Multiple senior stakeholders ▪ Multiple customers/ Multiple suppliers/ Multiple stakeholders ▪ Client demanding / unrealistic expectations ▪ High visibility/political ▪ Lack of control due to multiple project owners ▪ Senior support inappropriate ▪ Stakeholder engagement difficult to maintain ▪ Changing stakeholder requirements ▪ Uncertainty re information
Interfaces and interdependencies	▪ Lack of control due to multiple interfaces/owners ▪ Systems integration / multiple platforms ▪ Different design philosophies across platforms ▪ Different design philosophies across platforms ▪ Interdependence on other projects ▪ Upgrade of existing system / retrofitting ▪ Interdependency with environment ▪ Cross-organisational interdependencies ▪ Schedule interdependencies ▪ Quality integration
Technology	▪ Unknown technology / leading edge ▪ Very difficult technology ▪ Changing technological environment
Management processes	▪ Contractual relationships difficult ▪ Multiple contracts ▪ Contractor ethics / soft procurement practices ▪ Fast tracking / concurrent engineering / phases overlap ▪ Different technical issues with different contracts ▪ Supplier controlling cost / monopolies ▪ Supplier controlling availability
Work practices	▪ Cultural differences ▪ Cultural terminology differences ▪ Geographic distance/ time zones ▪ Internal cultures ▪ Multi-disciplinary ▪ Administrative processes to be adhered to ▪ Micro-reporting ▪ Split accountabilities/unclear authority ▪ Project personnel selection inappropriate ▪ Project methodology inappropriate ▪ Budgetary pressure
Time	▪ Change of decision makers over time ▪ Extended project history ▪ Lack of ability to define over time/ instability of requirements ▪ Relationships changing over time ▪ Plan constantly re-shaped ▪ Changing senior stakeholders

Table 5: Comparison of severity factors in the literature and from the interviews.

Factor from literature	Instances reported in the interviews
1.Difficulty	
2.Non-linearity	
3.Uncertainty	Imprecise information
4.Uniqueness	Unknown technology / leading edge;
5.Communication	Cultural terminology differences
6.Context dependence	Prior decisions difficult to accommodate; Changing senior stakeholders; Multiple senior stakeholders; Multiple customers; Multiple suppliers; High visibility/political; Multiple stakeholders Cultural differences Geographic distance/ time zones; Internal cultures; Multi-disciplinary; Administrative processes to be adhered to; Micro-reporting; Split accountabilities/unclear authority; Project methodology inappropriate Budgetary pressure Extended project history
7. Clarity	Customer unclear about goals; High level goals/ ill-determined; Inadequate requirements definition; Changing stakeholder requirements; Lack of control due to multiple interfaces/owners;
8. Trust	Contractor ethics / soft procurement practices;
9. Capability	Project personnel selection inappropriate;

Table 6: Comparison of dimensions in the literature and from the interviews

Factor from literature	Instances reported in the interviews
1. Goals	High level goals/ ill-determined;
2. Means to achieve goals	Different design philosophies across platforms; Very difficult technology; Contractual relationship difficult; Multiple contracts; Supplier controlling cost / monopolies Supplier controlling availability
3.Number of interdependent elements	Systems integration / multiple platforms; Interdependence on other projects; Upgrade of existing system / retrofitting; Cross-organisational interdependencies; Quality integration; Fast tracking / concurrent engineering / phases overlap; Different technical issues with different contracts
4.Timescale of project	Change of decision makers over time; Lack of ability to define over time/ instability of requirements; Relationships changing over time; Plan constantly re-shaped;
5. Environment	Changing technological environment;